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GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART 6 TESTS FOR VALIDITY OF A CONSTANT FAILURE RATE ASSUMPTION

Section 1 Chi-square Test

(Incorporating Amendment No. 1)

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Indian Standard

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PART 6 TESTS FOR VALIDITY OF A CONSTANT FAILURE RATE ASSUMPTION

Section 1 Chi-square Test

Reliability of Electronic and Electrical Components and Equipment Sectional Committee, LTDC 3

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GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART 6 TESTS FOR VALIDITY OF A CONSTANT FAILURE RATE ASSUMPTION

Section 1 Chi-square Test

0. FOREWORD

0.1 This Indian Standard (Part 6/Sec 1) was adopted by the Indian Standards Institution on 25 January 1983, after the draft finalized by the Reliability of Electronic and Electrical Components and Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard gives recommended numerical methods for testing the statistical validity of the constant failure rate assumption is the sixth in the series of Indian Standards for equipment reliability testing. To be able to write a detailed reliability test specification and perform a reliability test, the test engineer will need additional information which are dealt with in detail in other standards in this series. A list of standards envisaged in this series some of which are under consideration is given on page 10.

0.3 This standard is largely based on IEC Document 56 (Secretaries) 144 Draft IEC Standard 605 Equipment reliability testing: Part 6 Test for validity of a constant failure rate assumption, issued by the International Electrotechnical Commission.

0.4 This edition 1.1 incorporates Amendment No. 1 (November 1987). Side bar indicates modification of the text as the result of incorporation of the amendment.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part 6/Sec 1) gives recommended numerical methods for testing the statistical validity of the constant failure rate

*Rules for rounding off numerical values (*revised*).

assumption underlying the methods used in IS : 8161 (Part IV)* and IS : 8161 (Part VII)-1977*.

1.2 Recommendations are given for action to be taken in case the assumption is rejected. If stated in the detailed reliability test specification, one of these tests shall be applied before a conclusion is made from reliability testing of failure rate or mean time between failures.

2. GENERAL

2.1 The validity test shall be performed at the end of the reliability test using all relevant failures observed in the reliability test.

2.2 It shall be recognized that the validity tests are of a statistical nature and give results associated with certain small risks to reject the assumption when it is true. The tests in this standard (Part 6/Sec 1) are designed to a level of significance of 10 percent, that is, 10 percent risk to reject the assumption even if it is true. The risk should be considered together with the producer's risk of a reliability compliance test if the validity test is called for by the equipment contract or specification.

2.3 The proposed tests are the most generally accepted statistical validity tests for constant failure rate against any other (but unknown) distribution. The literature contains many tests of a constant failure rate against specific alternative hypotheses, such as increasing failure rate or decreasing failure rate. These tests could be used instead of the methods given in this standard.

2.4 Two tests are given one of which is limited to a large number of failures. Each test becomes more sensitive the more failures are observed. None of the tests is powerful enough to give significant departure from constant failure rate when the number of failures is small.

2.5 In case the reliability test is terminated before 3 relevant failures have been observed, for example, at compliance testing with acceptance at 0, 1 or 2 failures, and further testing is unfeasible because of economic, time or other reasons, an assumption of a constant failure rate may be permitted without the need of the test of validity.

2.6 If the testing is extended for information beyond the decision point of a reliability compliance test, the result of a validity test using all the data should only be used for information purposes. The additional data should not affect the decision made.

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*Guide for equipment reliability testing:

Part IV Procedure for determining estimates and confidence limits from equipment reliability determination tests (*under preparation*).

Part VII Compliance test plans for failure rate and mean time between failures assuming constant failure rate.

3. LIST OF SYMBOLS

3.1 The following symbols are used in this standard:

n = total number of test items;
r = total number of failures;
Tk = accumulated relevant test time up to the k : th failure;
Tr = accumulated relevant test time up to the latest failure;
T = total accumulated relevant test time;
d = parameter related to number of failures: if the validity test is done at a point in time coinciding with a failure $d = r–1$; if not d = r;
χ^2 = calculated value of the test statistic;
$\chi_p^2 (v)$ = theoretical value of the χ^2 distribution with v degrees of freedom at the fractile of order p;
u = number of intervals in the large sample test;
o_i = observed number of failures in the i : th interval;
e_i = expected number of failures in the i : th interval; (i = 1, ...,u); and
w_i = width of the i : th interval measured in accumulated time.

4. ACCUMULATED RELEVANT TEST TIME T AND PARAMETER *d*

4.1 The validity test are based on the accumulated relevant test times to failures with the addition of any relevant test time accumulated between the latest failure and the point of time at which the validity test is applied. Each of these accumulated times is the sum of the relevant test times of all the individual test items as recorded by elapsed time meters, work cycle counters or other appropriate means.

4.2 The relevant test time for the individual test items is defined in the detailed reliability test specification in accordance with **10.5** of IS : 8161 (Part I)-1976*.

4.3 If the validity test is to be carried out immediately after a number of failures, r, have occurred, that is, coinciding with a failure, the value of T equals Tr and the parameter d, related to the number of failures, equals $r–1$. If the validity test does not coincide with a failure, the parameter d equals r.

4.4 If the validity test is used in conjunction with a truncated sequential test covered in IS : 8161 (Part VII)-1977*, the same accumulated relevant test times may be used in the validity test.

*Guide for equipment reliability testing:
Part I Principles and procedures.
Part VII Compliance test plans for failure rate and mean time failures assuming constant failure rate.

5. PREFERRED TEST

5.1 The following test is recommended if the number of failures is between 3 and 30; if the number of failures exceeds 30 this test or the test recommended in **6** which is easier to calculate, may be used.

5.1.1 The accumulated relevant test times T_k, k = 1, 2,........, r, and T are calculated. The following test statistic shall be calculated:

$$\chi^2 = 2 \sum_{k=1}^{d} 1_\eta \left[\frac{T}{T_k} \right]$$

5.1.2 In the case of a constant failure rate, χ^2 is distributed as χ^2 ($2d$) with $2d$ degrees of freedom.

5.1.3 The calculated value χ^2 of the appropriate test statistic is compared with the theoretical values of χ_p^2 (v) given in Table 1. The two-sided test to be performed requires the values of p to be 5 percent and 95 percent for the level of significance of 10 percent. The number of degrees of freedom $v = 2d$.

If

$$\chi^2 < \chi_5^2 (v)$$

the assumption of a constant failure rate shall be rejected. The failure rate is likely to be increasing.

If

$$\chi^2 > \chi_{95}^2 (v)$$

the assumption of a constant failure rate shall also be rejected. The failure rate is likely to be decreasing.

6. ALTERNATIVE TEST FOR A LARGE NUMBER OF FAILURES

6.1 For a large number of failures, at least 30, a χ^2 goodness-of-fit test may be used instead of the test in **5**. The test is based on the accumulated relevant test times described in **4**.

6.2 The period between time zero and the accumulated time T at the validity test is divided into u intervals of width wi which need not all be equal. The expected number of failures in the i : th interval $e = wi\ d/T$ shall be equal to or greater than 5 with oi being the observer number of failures in the i : th interval. The following test statistic shall be calculated:

$$\chi^2 = \sum_{i=1}^{U} \frac{(o_i - e_i)^2}{e_i}$$

TABLE 1 χ^2 VALUES

(*Clauses* 5.1.3 *and* 6.3)

Degrees of Freedom (v)	$\chi^2_5\ (v)$	$\chi^2_{90}\ (v)$	$\chi^2_{95}\ (v)$
(1)	(2)	(3)	(4)
1	0.004	2.71	3.84
2	0.103	4.61	5.99
3	0.35	6.25	7.81
4	0.71	7.78	9.49
5	1.15	9.24	11.1
6	1.64	10.6	12.6
7	2.17	12.0	14.1
8	2.73	13.4	15.5
9	3.33	14.7	16.9
10	3.94	16.0	18.3
11	4.57	17.3	19.7
12	5.23	18.5	21.0
13	5.89	19.8	22.4
14	6.57	21.1	23.7
15	7.26	22.3	25.0
16	7.96	23.5	26.3
17	8.67	24.8	27.6
18	9.39	26.0	28.9
19	10.1	27.2	30.1
20	10.9	28.4	31.4
21	11.6	29.6	32.7
22	12.3	30.8	33.9
23	13.1	32.0	35.2
24	13.8	33.2	36.4
25	14.6	34.4	37.7
26	15.4	35.6	38.9
27	16.2	36.7	40.1
28	16.9	37.9	41.3
29	17.7	39.1	42.6
30	18.5	40.3	43.8
31	19.3	41.4	45.0
32	20.1	42.6	46.2
33	20.9	43.7	47.4
34	21.7	44.9	48.6
35	22.5	46.1	49.8
36	23.3	47.2	51.0

(*Continued*)

TABLE 1 χ^2 VALUES — *Contd*

DEGREES OF FREEDOM (v)	$\chi^2_5\ (v)$	$\chi^2_{90}\ (v)$	$\chi^2_{95}\ (v)$
(1)	(2)	(3)	(4)
37	24.1	48.4	52.2
38	24.9	49.5	53.4
39	25.7	50.7	54.6
40	26.5	51.8	55.8
41	27.3	52.9	56.9
42	28.1	54.1	58.1
43	29.0	55.2	59.3
44	29.8	56.4	60.5
45	30.6	57.5	61.7
46	31.4	58.6	62.8
47	32.3	59.8	64.0
48	33.1	60.9	65.2
49	33.9	62.0	66.3
50	34.8	63.2	67.5
51	35.6	64.3	68.7
52	36.4	65.4	69.8
53	37.3	66.5	71.0
54	38.1	67.7	72.2
55	39.0	68.8	73.3
56	39.8	69.9	74.5
57	40.6	71.0	75.6
58	41.5	72.2	76.8
59	42.3	73.3	77.9
60	43.2	74.4	79.1

NOTE — For degrees of freedom v>60, use $\chi^2_p = [(Z + \sqrt{2v-1})^2]/2$ where z is the corresponding percentage of the standard normal distribution.

6.3 The calculated value χ^2 is compared with the theoretical values of $\chi^2_p(v)$ given in Table 1. The one-sided test to be performed requires the value of p to be 90 percent for the level of significance of 10 percent. The number of degrees of freedom $v = u-1$.

If

$$\chi^2 > \chi^2_{90}(v)$$

the assumption of a constant failure rate shall be rejected. In this case it is not possible to assess whether the failure rate is decreasing or increasing.

7. ACTIONS TO BE TAKEN IF THE ASSUMPTION IS REJECTED

7.1 If the assumption of a constant failure rate is rejected by either of the validity tests, it may be useful to further analyse the data in order to determine what caused the rejection and to obtain information for the judgement of appropriate action to be taken.

7.2 An immediate conclusion from the rejection of a constant failure rate assumption is that the prerequisites for the reliability compliance tests covered in IS : 8161 (Part VII)-1977* are not fulfilled and that decisions based on those tests shall be questioned. The same applies for those estimates of IS : 8161 (Part IV)* of this standard that are based on constant failure rate and exponential distribution of times to or between failures. Another more appropriate distribution assumption may be found and the data statistically treated accordingly.

7.3 If the validity test shows that the failure rate is likely to be decreasing, indicating the existence of an early failure period, possible action would be to improve the quality control procedures of the equipment production or to institute burn-in of all the equipments.

7.4 If the validity test indicates an increasing failure rate, for example, due to wear-out failures, a possible action is to institute preventive maintenance by scheduled replacement of wearing parts prior to failure or to make design changes in order to avoid these parts.

7.5 Changes in design, production or preventive maintenance as well as introducing burn-in are all actions that have effect on the behaviour of the equipment. After any such action, new compliance, determination and/or validity tests should be performed on the modified equipment.

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*Guide for equipment reliability testing:

Part VII Compliance test plans for failure rate and mean time failures assuming constant failure rate.

Part IV Procedures for determining point estimates and confidence limits equipment reliability determination tests (*under preparation*).

INDIAN STANDARDS

ON

EQUIPMENT RELIABILITY TESTING

IS : 8161 Guide for equipment reliability testing:

(Part I)-1976	Principles and procedures
Part II	Design for test cycles (*under preparation*)
Part III	Preferred test conditions for equipment reliability testing (*under consideration*)
Part IV	Procedure for determining estimates and confidence limits from equipment reliability determination tests (*under preparation*)
(Part V)-1981	Compliance test plans for success ratio
(Part VI/Sec 1)-1983	Tests for validity of a constant failure rate assumption Section 1 Chi-square Test
(Part VII)-1977	Compliance test plans for failure rate and mean time between failures assuming constant failure rate
Part VIII	Tests for validity of a non-constant failure rate assumption (*under consideration*)
Part IX	Compliance test plans assuming Weiliull distribution of times to failure (*under consideration*)
Part X	Compliance test plans assuming normal distribution of times to failures (*under consideration*)
(Part XI)-1983	Flow chart describing preparations for and execution of reliability tests

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